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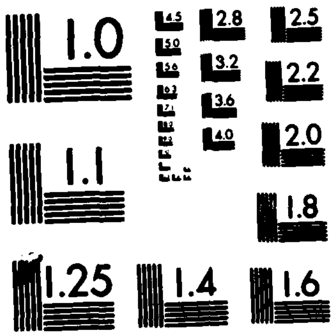
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AN AORTIC SIDEPORT CATHETER FOR RAPID HEMORRHAGE IN UNHEPARINIZED SWINE

L. WILLIAM TRAVERSO, MD, MAJ MC

JANUARY 1984

LETTERMAN ARMY INSTITUTE OF RESEARCH
PRESIDIO OF SAN FRANCISCO, CALIFORNIA 94129

An Aortic Sideport Catheter for Rapid Hemorrhage in Unheparinized Swine --Traverso

In conducting the research described in this report, the investigation adhered to the "Guide for the Care and Use of Laboratory Animals," as promulgated by the Committee on Revision of the Guide for Laboratory Animal Facilities and Care, Institute of Laboratory Animal Resources, National Research Council.

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20. ABSTRACT

Rapid hemorrhage is necessary to obtain reproducible mortality in chronically instrumented, unanesthetized, and unheparinized swine. Bleeding catheters could not always deliver the 3.6 ml/kg/min of blood necessary over the 15 minutes required by a rigid experimental design. Catheters become occluded before or during hemorrhage by thrombosis around the outside of the intraaortic portion of the catheter creating a one way valve. By shortening the intraaortic catheter portion to 2 mm from 10 mm and devising an operative technique to insert the catheter the failure rate significantly decreased from 18.8% (n=80) to 6.7% (n=149). The absence of a significant foreign body surface area in the blood stream allows the aortic sideport catheter to function as a rapid hemorrhage conduit many days later without the use of heparin.

ABSTRACT

Rapid hemorrhage is necessary to obtain reproducible mortality in chronically instrumented, unanesthetized, and unheparinized swine. Bleeding catheters could not always deliver the 3.6 ml/kg/min of blood necessary over the 15 minutes required by a rigid experimental design. Catheters become occluded before or during hemorrhage by thrombosis around the outside of the intraaortic portion of the catheter creating a one way valve. By shortening the intraaortic catheter portion to 2 mm from 10 mm and devising an operative technique to insert the catheter the failure rate significantly decreased from 18.8% (n=80) to 6.7% (n=149). The absence of a significant foreign body surface area in the blood stream allows the aortic sideport catheter to function as a rapid hemorrhage conduit many days later without the use of heparin.

Key Words: hemorrhagic shock; swine; unanesthetized; animal model.

The contents of LAIR Institute Report No. 168 have been submitted for publication in the open literature. In the interim, this report has been reproduced locally as an instructional aid.

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AN AORTIC SIDEPORT CATHETER FOR RAPID HEMORRHAGE IN UNHEPARINIZED SWINE

Development of an unheparinized hemorrhagic shock model was frought with frequent nonfunctional catheters for rapid hemorrhage. The arterial route offers the best chance of long-term catheter patency because rapid laminar flow around the catheter decreases thrombus formation. The ability to infuse through an arterial catheter can be extended up to 12 months if catheter fabrication prevents internal vascular damage and postoperative heparin flushing is maintained [2]. However, withdrawal of blood at a rapid rate is not possible in many of these functional infusion catheters because fibrin deposits soon form a sheath (a one-way valve) around the catheter [1].

This communication describes an experience with improving the patency rate (ability to withdraw blood at a rapid rate) of an abdominal aortic catheter. In a population of 229 swine the rate increased from an initial 78% to 95%. Construction of an aortic sideport accounts for this success. It exposes only the lumen to blood flow but not the outer wall of the bleeding catheter.

METHODS

Preparation of hemorrhage catheters. Catheters were placed through the side wall of the distal aorta. The catheter was sutured to the external wall of the aorta by means of a polyester patch secured firmly to the tubing with silicone rubber cement. The cement was allowed to dry for 24 hr and the catheter was then gas sterilized with ethylene oxide. The catheters were made of either silicone rubber or polyvinylchloride; and placed into three groups according to material, diameter, and distance of protrusion into the aortic lumen (Table 1).

Table 1
Catheter Specifications

Group	Material	I.D. (mm)	O.D. (mm)	Protrusion(mm)
A	Silicone Rubber	1.5	2.5	10
B	Polyvinylchloride	1.8	2.8	10
C	Polyvinylchloride	1.8	2.8	2

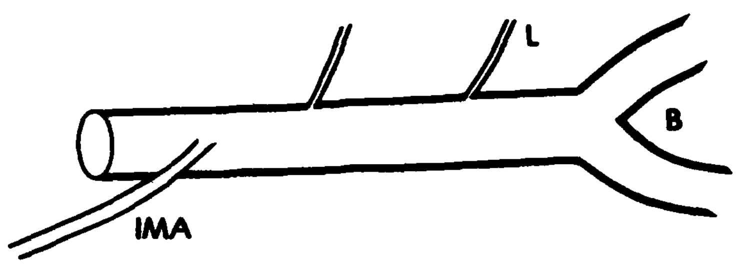

Figure 1. Side view of distal aorta seen through left flank incision after retroperitonal blunt dissection. An umbilical tape is placed around the aorta for countertraction during application of the aortic clamp. The underlying vena cava or a lumbar branch must not be injured by excessive traction. IMA = caudal (inferior) mesenteric artery. L = lumbar artery branch. B = aortic bifurcation.

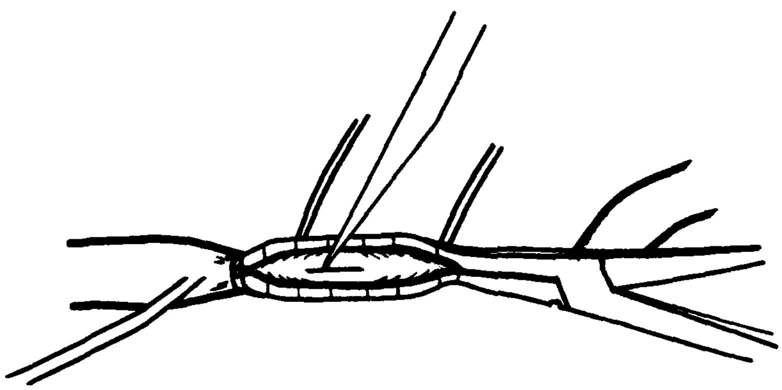

Figure 2. The Cooley aortic clamp occludes the distal aorta and isolates an aortic segment allowing catheter placement without having to dissect the entire aorta circumferentially from the underlying vena cava and a rich lymphatic system. The clamp is placed over the lumbar arteries and may include a portion of the vena cava.

Surgical implantation. Details for sterile placement of a bleeding catheter in immature female domestic swine (14-25 kg) has been outlined previously [3]. Briefly the infrarenal aorta was approached by a left flank incision and blunt retroperitoneal dissection. The left side of the aorta was dissected free between the origin of the caudal (inferior) mesenteric artery and aortic bifurcation, preserving all lumbar branches (Fig. 1). An umbilical tape was placed around the aorta just cranial to the last lumbar arterial branch. The aorta was elevated with the tape and then a vascular clamp (16.5 cm Cooley forceps with Derra-type jaws, 45 mm long, C#6235, American V. Mueller Co., Chicago, Illinois) was used to occlude the vessel. A 6-mm longitudinal aortotomy was made with a #11 scalpel blade (Fig. 2). The catheter was sewn in place with 4-0 braided polyester cardiovascular suture according to the method outlined in Figures 3, 4, and 5. The catheter was then tunnelled between the paravertebral muscles and the lumbar vertebral column to exit the skin in the mid-dorsal lumbar region. All catheter tubing was originally cut to a length of 30 cm from the polyester patch to the external end. Once tunnelled, the tubing was cut to leave 2 cm protruding from the skin and an infusion plug (Jelco intermittent injection cap #4600, Critikon Co., Tampa, Florida) was attached with a No. 14 blunt needle. A column of saline could then be placed throughout the catheter, preventing blood from entering the aortic end.

The resulting in situ catheter was 20 cm, including the 2-cm external portion, and was anchored to the skin using 3-0 nylon suture tied with multiple nonbinding loops in a "Chinese handcuff" method. The catheter was protected by passing it through a slit in a Velcro patch and then attaching the patch to the skin with nylon sutures and applying a detachable Velcro cover over the catheter and patch. The catheter was neither flushed nor manipulated until experimental hemorrhage 5 days later. If a catheter was nonfunctional at the time of hemorrhage, the animal was given a euthanasia solution and the catheter examined in situ in the distal aorta.

RESULTS

During a 10-month period, distal aortic catheters were implanted in 229 swine. Twenty-five catheters (10.9%) failed to function; i.e., blood could not be withdrawn at all or blood could be withdrawn but too slowly to comply with the hemorrhagic shock protocol. The results are expressed in Table 2 by catheter type and intralumen length.

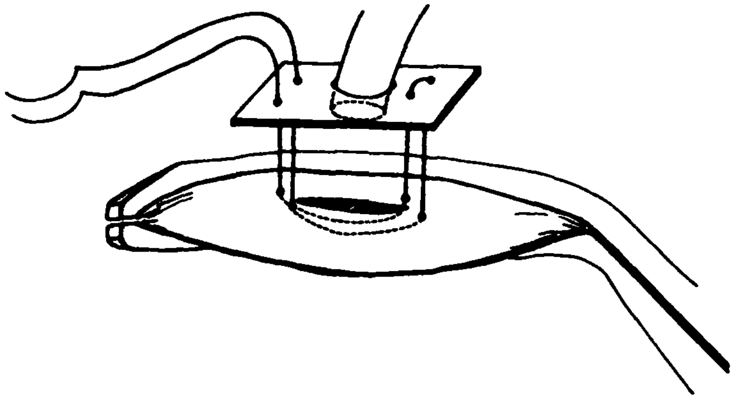

Figure 3. A double armed cardiovascular suture firmly attaches the polyester patch over the longitudinal aortotomy. The suture is placed as close to the aortotomy as possible to avoid a "tuck" in the aortic wall which might partially or totally occlude blood supply to the lower extremities. This complication will become evident during the immediate postoperative period.

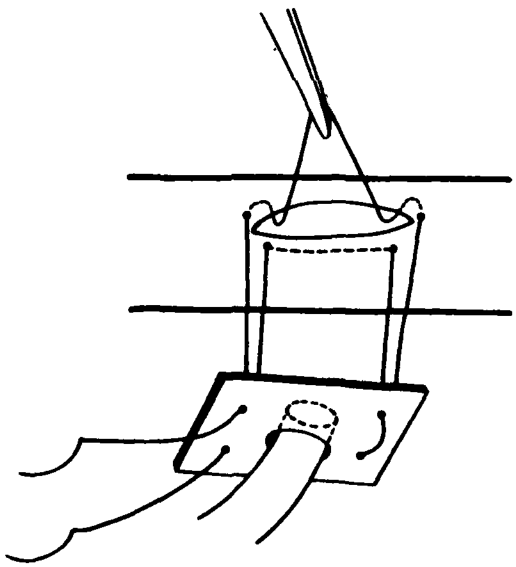

Figure 4. The short catheter tip is easily slipped through the aortic incision if the back wall of the aortotomy becomes elevated by retracting the upper suture with forceps. Care should be taken to insure that after tying the suture it does not course over the catheter lumen but rather along the catheter's outside periphery near the patch. If either suture stretches over the lumen, a nidus for thrombosis results and makes the catheter nonfunctional.

Table 2

Summary of Catheter Failures

Group	Catheter Type	Total	Failures	%Failures
A	Silicone rubber, long	54	10	18.5
B	Polyvinyl, long	26	5	19.2
C	Polyvinyl, short	149	10	6.7
	All catheters	229	25	10.9

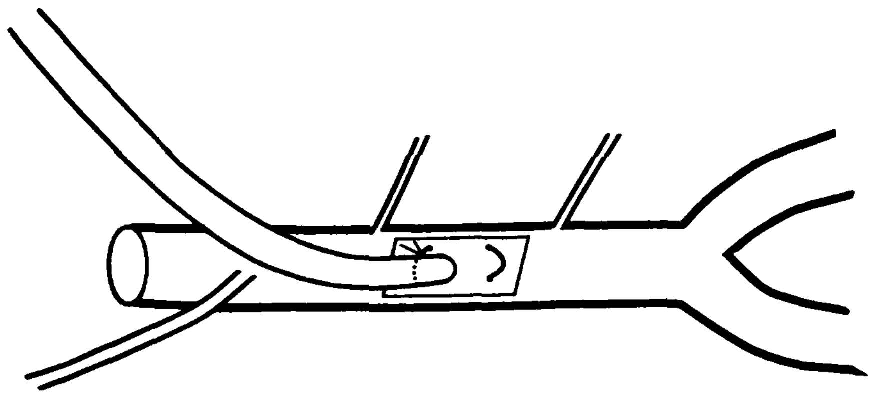

Figure 5. The patch is sewn into place; no further catheter attachment, except at the skin, is necessary. The silicone rubber cement must be allowed to dry for 24 hours before sterilization and catheter use, or the short catheter will slip out of the patch into the retroperitoneum. This is not fatal since the patch hole quickly clots and the result is simply a nonfunctional catheter.

Within the overall 10.9% failure rate, the short polyvinyl catheter resulted in the lowest incidence of failure (6.7%, p=0.025, chi-square test). The higher failure rates were associated with the long-tip catheters. If the catheter extended into the lumen for 10 mm, the failure rate was the same regardless of the tubing material--silcone rubber (18.5%) versus polyvinylchloride (19.2%).

As these results became apparent, the short polyvinylchloride catheter was used exclusively and in the 79 most recent catheterizations only four catheters (5.0%) were nonfunctional.

During in situ examination, the nonfunctional catheters, all were occluded by a thrombus around, but not inside, the catheter or by a thrombus arising from the area of the opposite aortic wall where it was touched by the long catheter (Fig. 6).

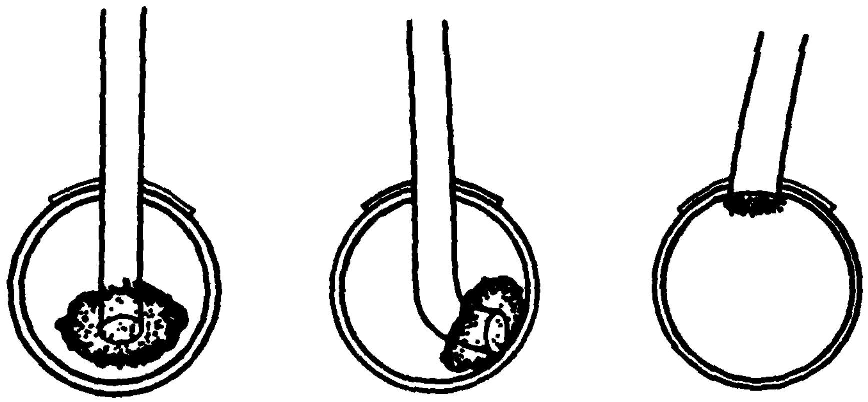

Figure 6. The types of thrombi induced by the catheter are depicted. The catheter alone can be surrounded by a thrombus (left) or the thrombus can arise from injured endothelium where the catheter contacts the opposite wall (middle). The short-tipped "sideport" catheter does induce a thrombus, but without an outside area of attachment the clot is easily removed by flushing or aspiration (right).

DISCUSSION

To provide clinically relevant data, a hemorrhagic shock model should be unmedicated and unheparinized. The ideal hemorrhage catheter should remain functional to allow recovery from surgery before hemorrhage and should not require heparin to stay patent. When ready to be used the catheter must provide for rapid removal of blood to achieve a reproducible mortality rate. Our protocol, for instance, calls for removal of 60% of the estimated blood volume (EBV) within 15 minutes [3]. Because of the required rapid bleeding rate, various arterial catheter sites were tried before settling on the distal aorta. The carotid artery proved unreliable for two reasons. The catheter must be advanced to the carotid artery origin at the aortic arch to remain patent because any remaining carotid lumen will thrombose ahead of the catheter. Since catheter advancement must be accomplished blindly, the catheter may clot secondary to inadequate insertion or protrude so far into the aortic arch as to occlude the adjacent porcine carotid artery. The resultant decrease in central nervous system blood flow caused an artifactually high 86% mortality when 60% EBV was removed in only 60 minutes [3]. The proximal aorta site was used, but the thoracotomy to place the catheter was an unnecessarily severe stress when compared to the less invasive and faster retroperitoneal dissection through the left flank to expose the distal aorta. The "skin-to-skin" procedure time to cannulate the distal aorta by the method outlined in this paper is less than 20 minutes.

At first silicone rubber catheters were used. We hoped to induce less clot formation but, regardless of catheter material, the catheter failure rate was a consistent 13% whenever any portion of the catheter protruded into the aortic lumen. Long-tipped catheters cause turbulence in the rapid laminar flow of the aorta and allow clot formation around the protruding catheter. Despite flushing or obturator insertion, the clot acts as a one-way valve. Though nonfunctional for blood removal, these catheters allow infusion of solutions. At autopsy, the clot can be found attached either around the catheter tip only or to the catheter and the immediately opposite aortic wall where the catheter tip evidently had injured the endothelium. Because of these problems, we switched to a short-tip catheter hoping to minimize turbulence.

The catheter insertion technique was improved (Fig. 4) to allow us to place a sideport into the aortic lumen which barely projected through the aortic wall. Whenever the short tip of the catheter was cut longer than 2 mm, a clot still formed that could not be removed by flushing. Evidently, the small clot that forms over the opening of the catheter when it does not protrude from the aortic wall (Fig. 6) can be easily dislodged by gentle aspiration or flushing. Although the current patency rate of 95% is acceptable, the reason for the occasional failure remains consistent: protrusion of the catheter into the aortic lumen. In this case a small but tenacious clot that forms on minimally but definitely protruding catheters can be bypassed by passing a rigid polyethylene inner catheter (PE 240, I.D.=1.67 mm, O.D.=2.42 mm, Clay Adams Co., Parsippany, New Jersey) through the clot (Fig. 7). Doing this simple procedure has reduced catheter failures even further in the most recent studies.

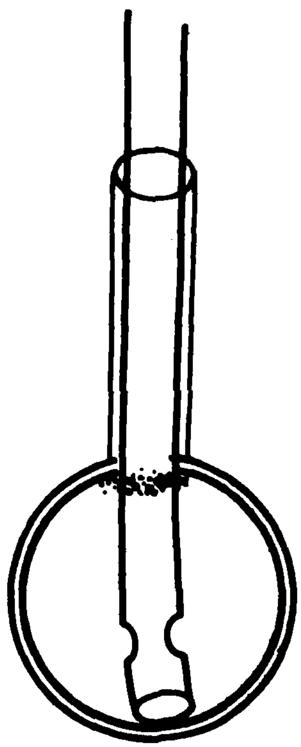

Figure 7. If a clot becomes firmly attached, a rigid PE240 tube can be inserted through the clot into the aorta. Side holes mist be cut as depicted because the catheter tip is occluded during blood withdrawal by the adjacent aortic wall.

CONCLUSIONS

Exsanguination (3.6 ml/kg/min) is successfully completed over 15 minutes from unanesthetized, unheparinezed swine if an aortic side-port catheter is used. The catheter is placed five days prior to hemorrhage. The success rate is greater than 93%.

RECOMMENDATION

Chronic animal hemorrhage models requiring rapid exsanguination can avoid heparin and obtain successful hemorrhage in a reproducible and rapid manner by using the aortic sideport catheter.

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